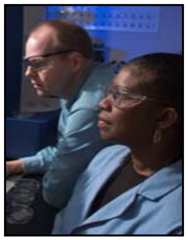
Overview of the SRS Waste Tank Structural Integrity Program




SRNL™
SAVANNAH RIVER NATIONAL LABORATORY

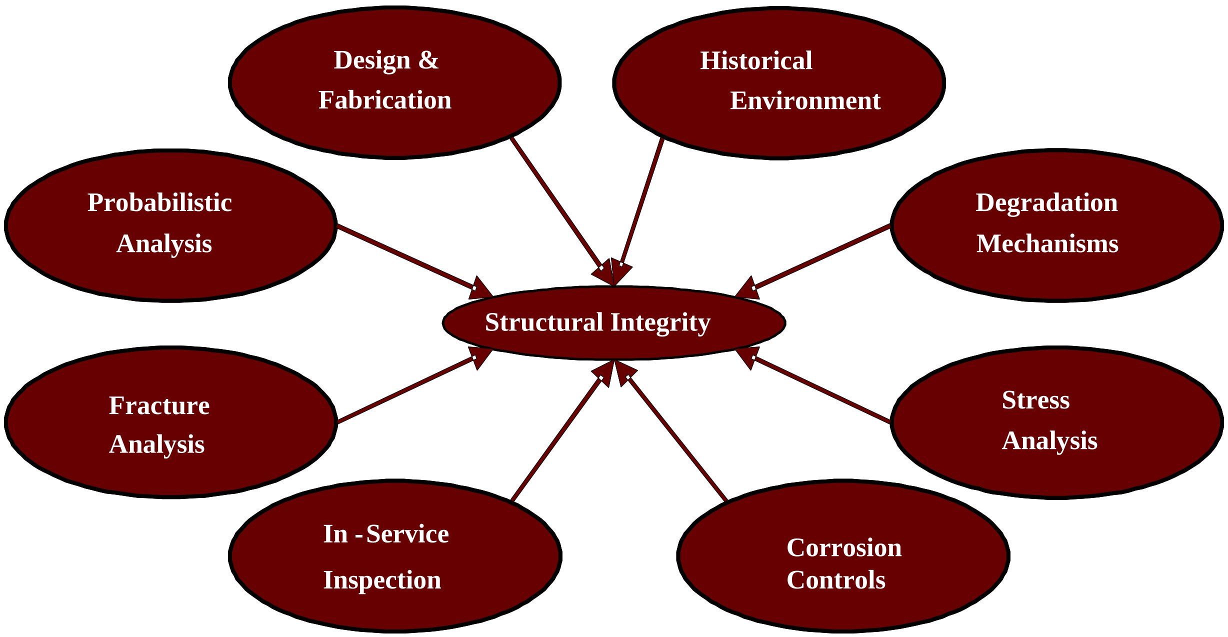
We Put Science To Work

B. J. Wiersma

Materials Science and Technology

Mission and Approach

Mission of Structural Integrity Program: To ensure continued safe management and operation of the waste tanks for whatever period of time these tanks are required.

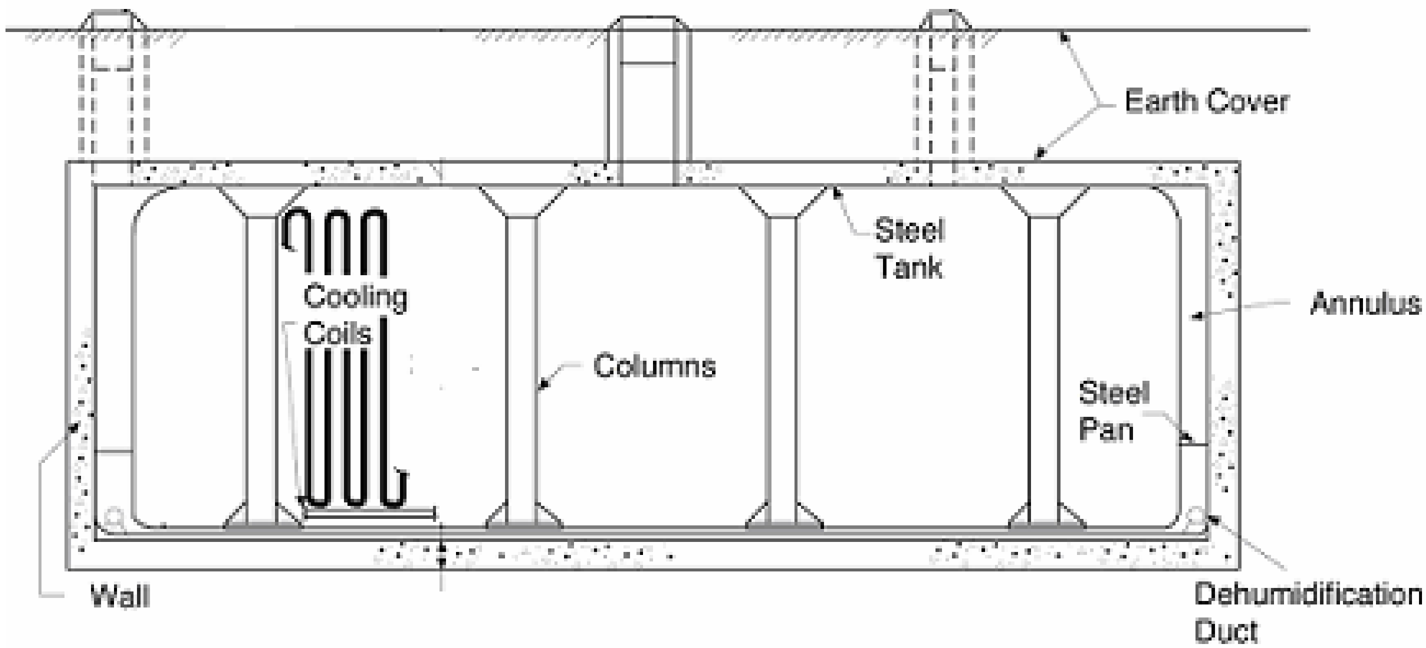


Recognized as strategic for the DOE-EM Engineering and Technology Roadmap Structural Integrity Initiatives.

SRNL

Design and Fabrication

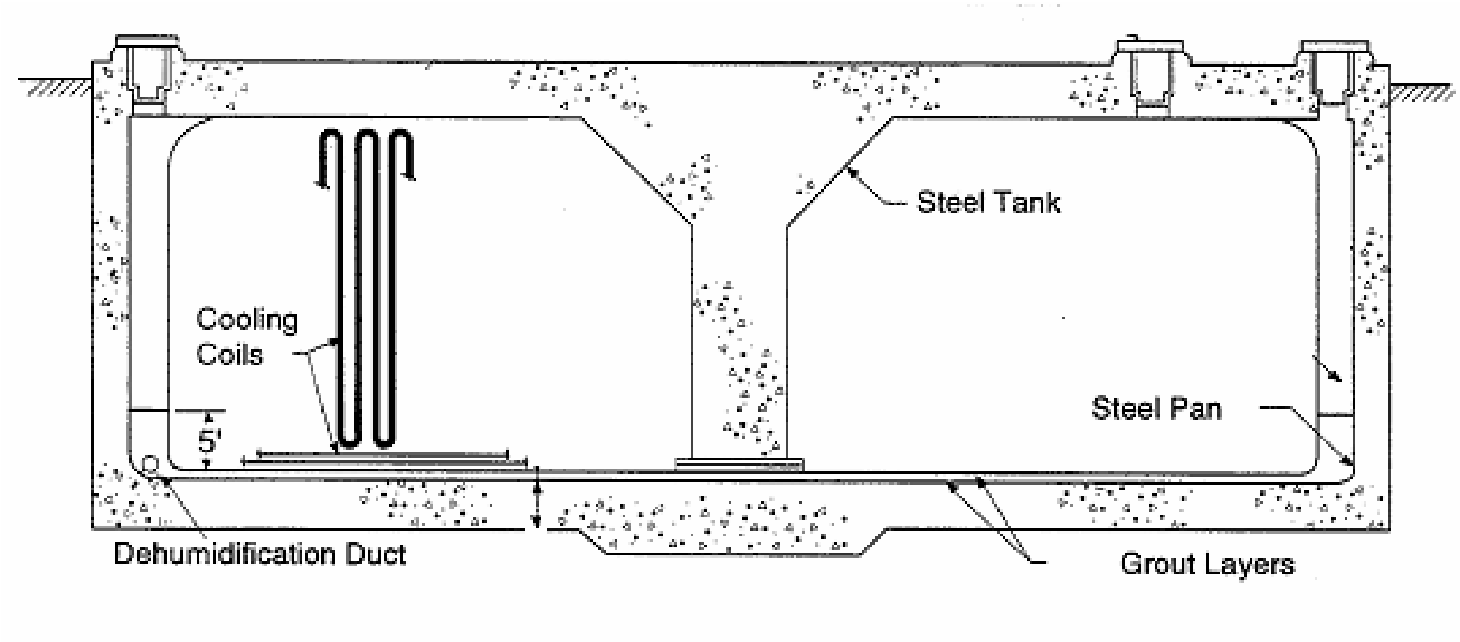
Type I Tank: 1951-1953



SRNL

Design and Fabrication

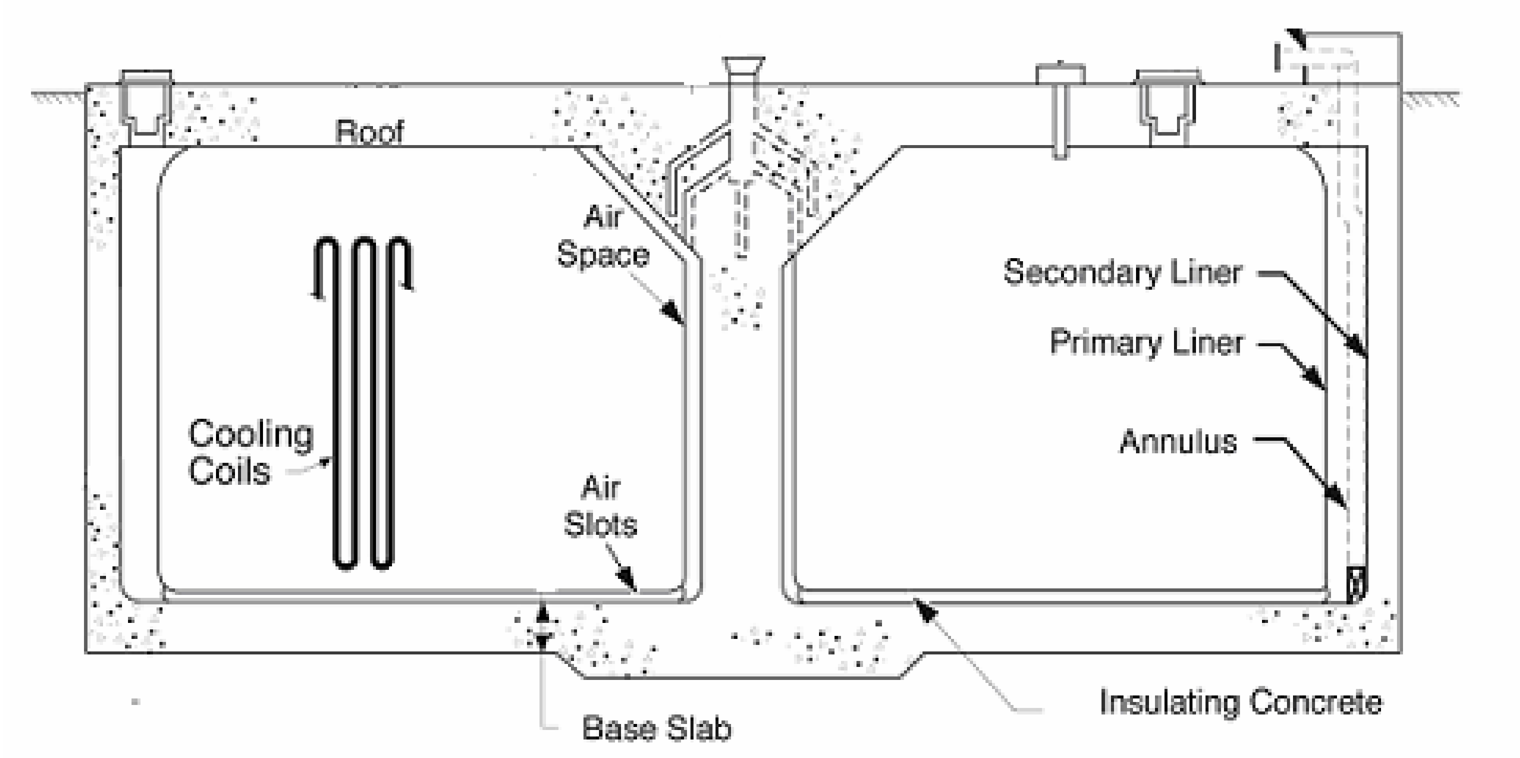
Type II Tank: 1955



SRNL

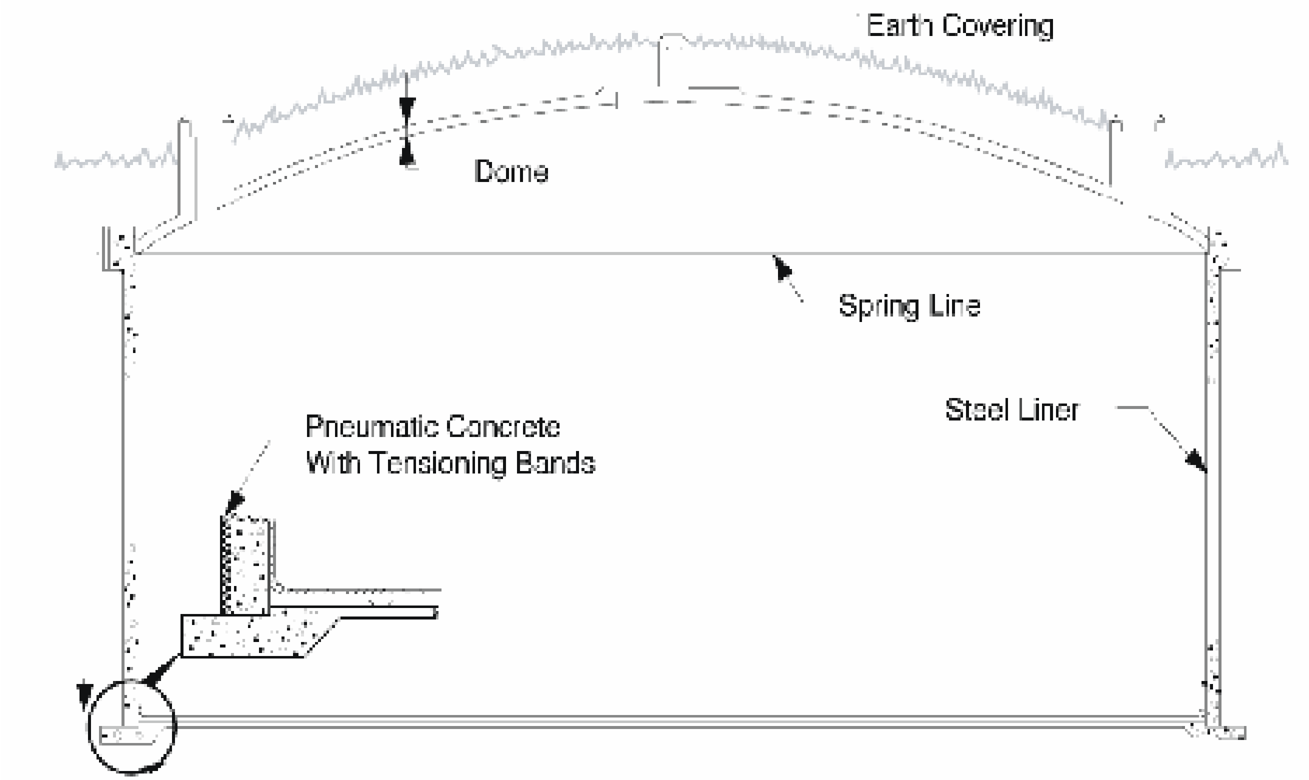
Design and Fabrication

Type III/IIIA Tanks: 1967-1981



Design and Fabrication

Type IV Tanks: 1958-1962



SRNL

Design and Fabrication

TANK MATERIALS OF CONSTRUCTION EVOLVED BASED ON DEGRADATION CONCERNS

ASTM A285-B Carbon Steel (Type I and II, and IV)

↓

ASTM A212-B Carbon Steel (Type IV)

ASTM A516-70 Carbon Steel (Type III)

↓

ASTM A516-70 (Normalized) Carbon Steel (Type III)

↓

ASTM A537 Class I Carbon Steel (Type IIIA)

- Improved resistance to SCC and brittle fracture
- Stress-relief of Type III/IIIA primary

SRNL

Historical Environment

- Three forms:

  Supernate - liquid waste from the fuel processing facility

  Sludge – solid metal oxides that settle to the bottom of the tank (iron, manganese, etc.)

  Saltcake – Solid crystallized waste that has returned from the evaporator.

SRNL

Historical Environment

- Concentration Range of Major Anion Constituents in Supernate

Waste	Nitrate (M)	Hydroxide (M)	Nitrite (M)	Form
Fresh	1-5	0.6-1.5	0.5 -1	Sup/Sl
Salt Receiver	1-3	3-13	0.5 -1.5	Sup/Sa
Dilute Low-Level	0.01-0.5	0.01-0.6	0.01 -.5	Sup

- Temperatures during storage and operation

Waste	Supernate (C)	Salt (C)	Sludge (C)
Fresh	50-70	-	120-140
Salt Receiver	30-50	50-80	-
Dilute Low-Level	20-35	-	-

SRNL

In-Service Inspection

- Routine Visual Imagery Techniques (1971- present)
  - Wide-angle Photography (field of view ~100°)
  - Direct Photography by Shielded Camera
  - Closed Circuit Television
  - Percentage of tank viewed from the annulus:
    - Type I: 13-75%
    - Type II: 73-96%
    - Type III/IIIA: 100%
  - Interior of Type IV tank walls and concrete dome inspected
- Summary of visual observations
  - Direct visual detection of leaksites (Type I and II)
  - Visual of liquid/salt in secondary tank pan (Type I and II)
  - Rainwater intrusion through liner of Type IV
  - Minor Surface Corrosion on Outer Walls (Type I, II, III)

SRNL

In-Service Inspection

- Wall Thickness Measurements 1971-1985 (Type I, II, III, IV)
  - > 24,000 point measurements
  - No reportable wall thinning
- P-scan 1994 (selected Type IIIA: Tanks 40, 42 & 48-51)
  - No reportable wall thinning or pitting observed
- P-scan 2002-2007 (All Type III/IIIA tanks and 1 Type II Tank)
  - No reportable wall thinning or pitting observed (2002-2007)
  - No cracks observed on Type III/IIIA tanks (2002-2007)
  - Stress Corrosion Cracks on Type II tank were characterized in 2002 and 2007.

SRNL

Degradation Mechanisms for Tank Steel

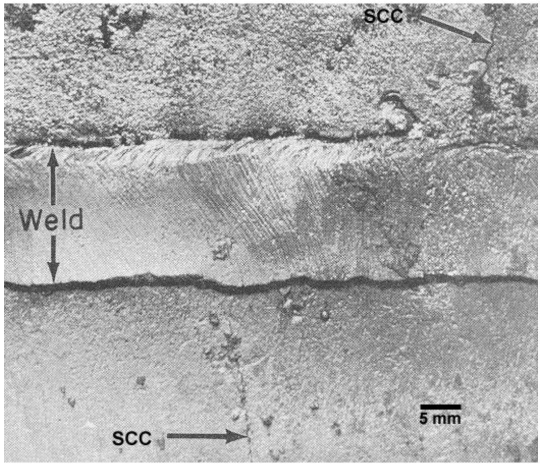
Waste Storage Conditions

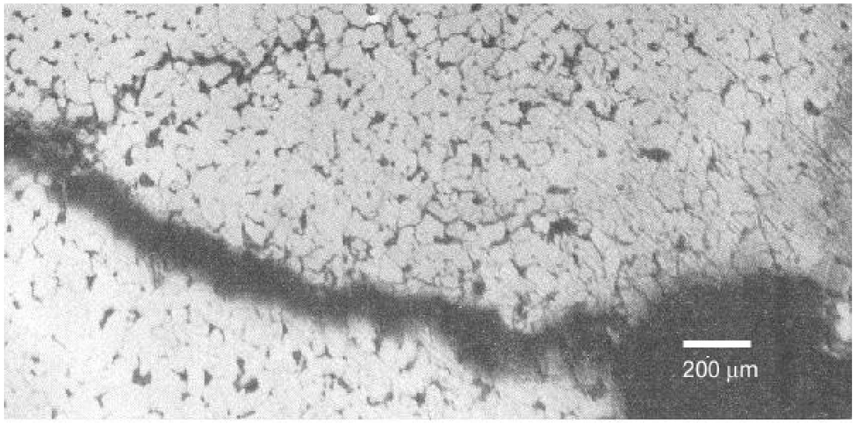
- Significant
  - Stress Corrosion Cracking
  - Pitting/Liquid-Air Interface
- Insignificant
  - Uniform or General Corrosion
  - Microbiologically Influenced Corrosion
  - Thermal Embrittlement
  - Radiation Embrittlement
  - Fatigue
  - Creep
  - Erosion and Erosion/Corrosion
  - Hydrogen Embrittlement

SRNL™

Degradation Mechanisms

- Type I and II Tanks
  - Exposure to Fresh Waste with no corrosion control program.
  - Cracks initiated near welds weld attachments or weld repairs.
  - Cracks are short range, typically less than 6 inches.
  - 9 of 16 waste tanks exhibited cracks early in service (< 2 years)
  - Nitrate induced intergranular stress corrosion cracking.
  - Extensive laboratory study to demonstrate the benefits of post-weld heat treatment to relieve weld residual stresses.

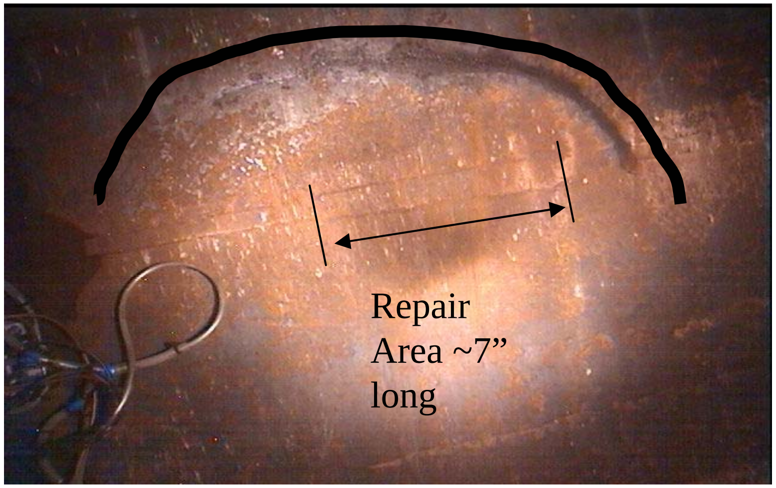




SRNL

Degradation Mechanisms

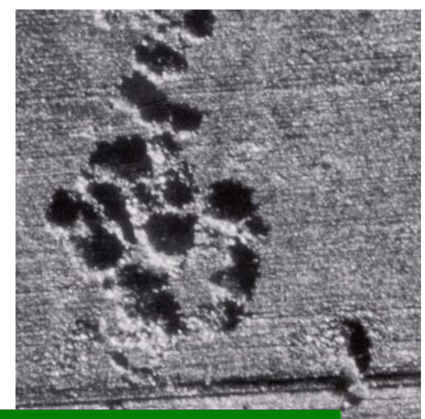
- Type I and II Tanks
  - Exposure to tank vapor space
  - Through-wall cracks have appeared several years after exposure to liquid waste.
  - 4 of 16 waste tanks have exhibited these types of cracks since 1994.
  - Performed UT measurements on cracks in one Type II tank in 2002 and 2007.
  - Cracks associated with welds, weld attachments, and weld repairs. Cracks are typically short range.
  - Mechanism of initiation and growth not reproduced in the laboratory.



SRNL

Degradation Mechanisms

- Pitting in vapor space and at liquid/air interface
  - Observed in the laboratory environment: High pH (>10) dilute supernate
  - Stagnant interface
  - Depletion of hydroxide inhibitor due to absorption and reaction with carbon dioxide; Insufficient nitrite inhibitor
  - Minor pitting at defects in the oxide was observed
  - Not observed during UT measurements in the waste tanks.



Localized Pitting

SRNL

Corrosion Control

Applicability	Parameter	Minimum Needed	Units
$5.5 < [NO_3^-] \leq 8.5$ Molar	$[OH^-]$	0.6	Molar
	$[OH^-] + [NO_2^-]$	1.1	Molar
$2.75 < [NO_3^-] \leq 5.5$ Molar	$[OH^-]$	0.3	Molar
	$[OH^-] + [NO_2^-]$	1.1	Molar
$1.0 < [NO_3^-] \leq 2.75$ Molar	$[OH^-]$	0.1 $[NO_3^-]$	Molar
	$[OH^-] + [NO_2^-]$	0.4 $[NO_3^-]$	Molar

- Inhibitor requirements for SCC prevention
- Based on slow strain rate and WOL tests

SRNL

Corrosion Control

- Local depletion of the hydroxide could result low pH (10.3) condition at the liquid air interface. Sufficient nitrite in the bulk solution was shown to prevent the initiation of nitrate pitting corrosion.

- Electrochemical tests and coupon immersion tests were used to determine a minimum nitrite concentration as a function of nitrate concentration and temperature that will prevent pitting initiation.

$$[NO_2^-] = 0.038\ [NO_3^-]\ 10^{(0.041\ T)}$$

Corrosion Control

Table 2.6.2-2 Sample Frequency for Waste Tanks*

	Category	Frequency	Deadline for Analytical Results Incorporation in ERD
ACTIVE WASTE TANKS	Evaporator Feed Tanks and Drop Tanks	3 Months	First regularly scheduled ERD** after 90 days from sample date
	Receiver With Nitrate Concentration Less Than 1 Molar	3 Months	First regularly scheduled ERD** after 90 days from sample date
	Receiver With Nitrate Concentration Greater Than or Equal to 1 Molar	6 Months	First regularly scheduled ERD** after 90 days from sample date
	SLURRIED WASTE TANKS***	1 Month **AND** Within 1 month after slurry pumps/mixers are stopped	First regularly scheduled ERD** after 90 days from sample date
STATIC WASTE TANKS	Nitrate Concentration Less Than 1 Molar	3 Months	First regularly scheduled ERD** after 90 days from sample date
	Nitrate Concentration Greater Than 1 Molar and Hydroxide Concentration Less Than 3 Molar	1 Year	First regularly scheduled ERD** after 90 days from sample date
	Nitrate Concentration Greater Than 1 Molar and Hydroxide Concentration Greater Than 3 Molar	4 Years	First regularly scheduled ERD** after 90 days from sample date

SRNL

Corrosion Control

- Exterior Tank Wall
  - De-humidified air flows through the annulus.
  - Maintain Minimum Primary Wall Temperature > NDTT, particularly for Type I and II tanks
  - Prevents dissolution of salt deposits
  - Prevents significant general corrosion of primary
  - Limits on Time to Restore to Operation
    - Type I and II Tanks: 30 Days
    - Type III Tanks: 90 Days

SRNL

Stress Analyses

- Primary tank, secondary liner and concrete vault for all waste tank types were evaluated for the demands resulting from operating and natural phenomena hazard (NPH) loads.
- Primary tank
  - Type I and II: ASME Section VIII, Div. 2
  - Type III/IIIA: ASME Section III, Div. 1, Subsection NC-3200

SRNL

Stress Analyses

- Seismic structural analysis was based on site-specific geotechnical information per DOE order 6430.1.
  - 1995 areas of concern were slope stability, shallow liquefaction, and subsidence of “soft zones”.
- All tanks have been analyzed for tank top equipment loads.

Fracture Analyses

- Fracture Analysis (FAD)
  - Utilized API 579 Fitness-for-Service Approach
  - Site specific material properties
  - Fill limit calculations for Type I and II tanks with cracks
- Fracture Analysis J-integral
  - Utilized J-T approach
  - Evaluated specific cracks in Type I and II tanks
- Comparison of two methodologies demonstrated no difference for this application.

SRNL

Summary

- SRS has had a routine inspection and corrosion control program for nearly 35 years. These programs have addressed general, pitting and stress corrosion cracking.
- Inspections have demonstrated the effectiveness of stress relieving the tanks and that the corrosion control program has effectively mitigated known degradation mechanisms.
- No significant pitting or wall thinning has been observed in the vapor space of the tanks. However, some through-wall cracks have appeared in non-stress relieved tanks while exposed to a vapor space environment. These cracks are also associated with the welds.
- Methodologies are in place to disposition existing cracks.
- Challenge: Devise a scheme that optimizes inhibitor additions during waste removal, while minimizing additional waste.

SRNL™